Nuclear Physics & Astrophysics

Exercises – 1

Hand in on 1st floor by Friday 8th October 2pm

Proton mass m_p = 1.00727647 u
Neutron mass m_n = 1.00866501 u
Avogadro's number N_A=6.022 x 10^{23} mol^{-1}

1. Give the atomic number, atomic mass number and neutron number of the nucleus Ne_{11} [2]

2. A neutron star is a collapsed star composed entirely of neutrons. Assuming this to be rather like a large astrophysical nucleus, what is the mass of $1cm^3$ of matter from the neutron star. [2]

3. The mass of a ^{18}O nucleus is 17.999160u. Convert this mass into units of MeV/c^2 [2]
   Working in units of MeV/c^2, compare this to the mass of $8m_p+8m_n$ where m_p and m_n are the masses of the proton and neutron. Why is the nuclear mass different from the sum of nucleon masses? Explain what has happened to the missing mass. [6]
   a) Calculate the average mass difference per nucleon in ^{18}O. Assuming the same average mass difference per nucleon in ^{235}U determine the total mass difference for ^{235}U [2]
   b) Convert the total mass difference for ^{235}U to energy in units of MeV [2]
   c) Assuming only 10% of this energy is released in a nuclear reactor, calculate the total energy released for 1 mole of ^{235}U. [4]
   d) The heat of combustion of ethanol is 1300 kJ/mole. Compare the energy released in Joules from burning 1 mole of ethanol to the energy released from 1 mole of ^{235}U above. [2]

4. Calculate the potential energy in MeV due to Coulomb repulsion of:
   a) 2 protons separated by 1 fm [2]
   b) a gold nucleus (Z=79) and an α-particle with centres 10 fm apart [2]

5. A physicist sets up four experiments to measure the decay rate of an unknown sample of radioactive material under different environmental conditions. The sample is divided into four identical parts and placed within identical apparatus to measure the decay rates. The following experiments are performed:
   a) at standard temperature an pressure in the laboratory
   b) at high atmospheric pressure
   c) at high temperature
   d) in zero gravity

   Which of the experiments yields the highest decay rate? Why? [2]

[PTO…]

6. Read the lecture notes on carbon dating (lecture 3). Estimate approximately the range of time in the past that can be dated using this technique . [2]
^{41}Ar is also produced by the bombardment of cosmic rays in the upper atmosphere. Give two reasons why this radionuclide is not suitable for radio-dating. [4]